CCSDS
Architecture Working Group

Architectural Models of Space Networking

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AGENDA

- Overview and Drivers
- Architectural Viewpoints
- Example Reference Architecture (RASDS) Views
- Application of RASDS to Space Internetworking
- Next Steps

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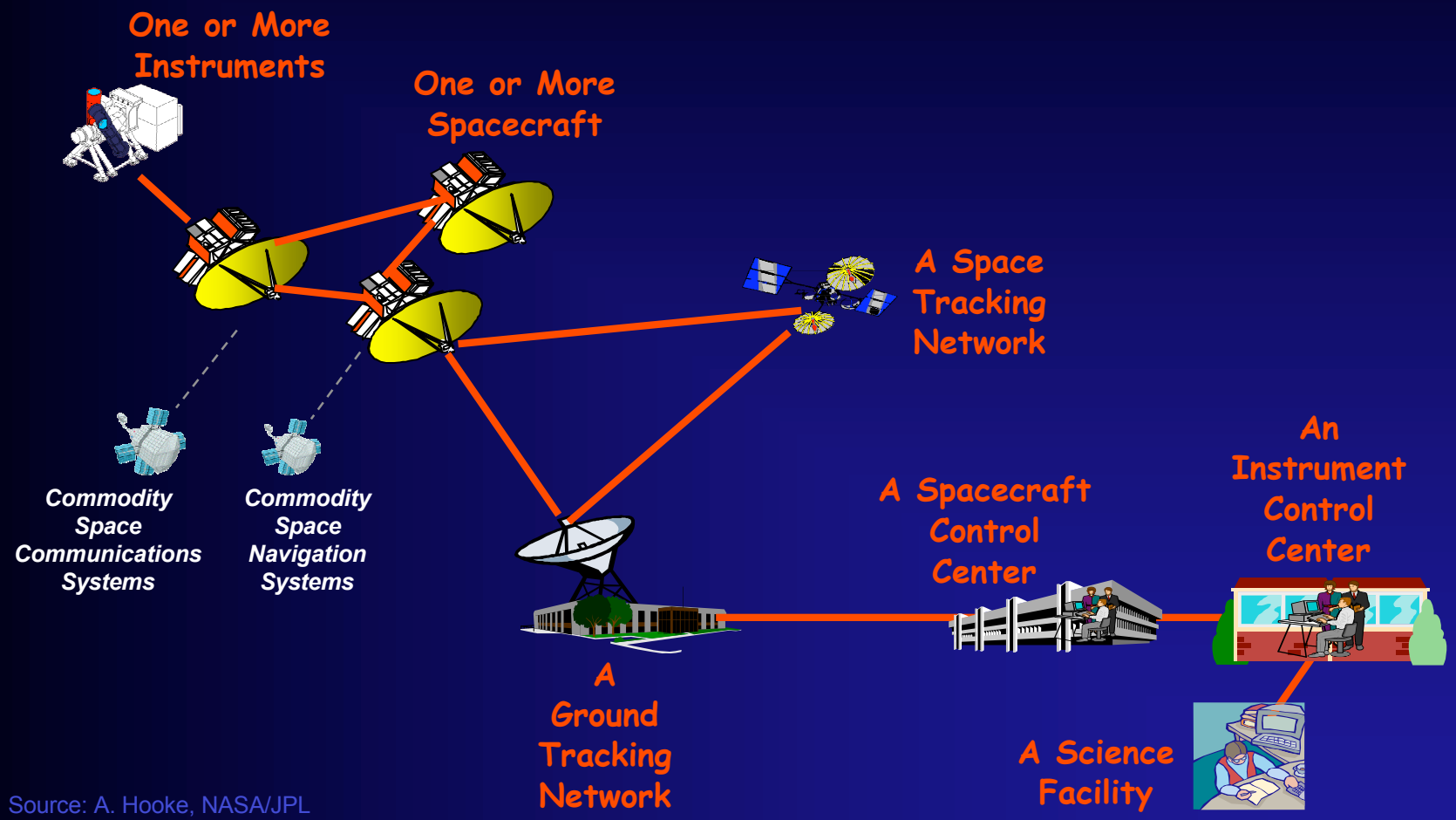
A Physical View of a Space Data System



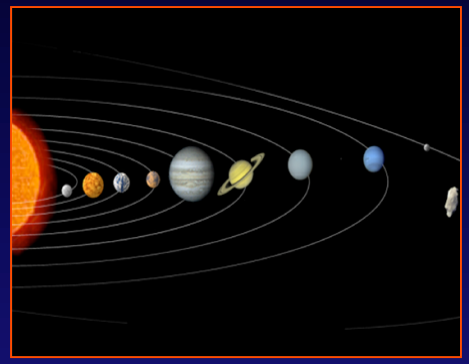
Source: A. Hooke, NASA/JPL

Space Mission Drivers

- **INCREASED SPACE SEGMENT CAPBILITIES**
  - **More miniaturization, more missions, more bang for the buck**
  - **Higher date rates, more powerful onboard processing**
  - **Constellations and Formation Flying**
    - **Inter Spacecraft Communications**
    - **Positioning Relative to Each Other**
  - **Autonomous Exploration**
    - **Less reliance on "Joystick Operations."**
    - **Dynamic Response to Environment (Precision EDL, Rendezvous & Docking)**
  - **Highly networked**
    - **Re-configurable web of orbiting and landed sensors for in-situ, long-term and detailed observation, prediction and analysis.**
- **HIGHLY DISTRIBUTED MULTI-ORGANIZATION DESIGN AND OPERATIONS TEAMS**

Space Data System

Several Architectural Viewpoints



Enterprise

Business Concerns
Organizational perspective

Connectivity

Physical Concerns
Node & Link perspective

Functional

Computational Concerns
Functional composition

Information

Data Concerns
Relationships and transformations

Communications

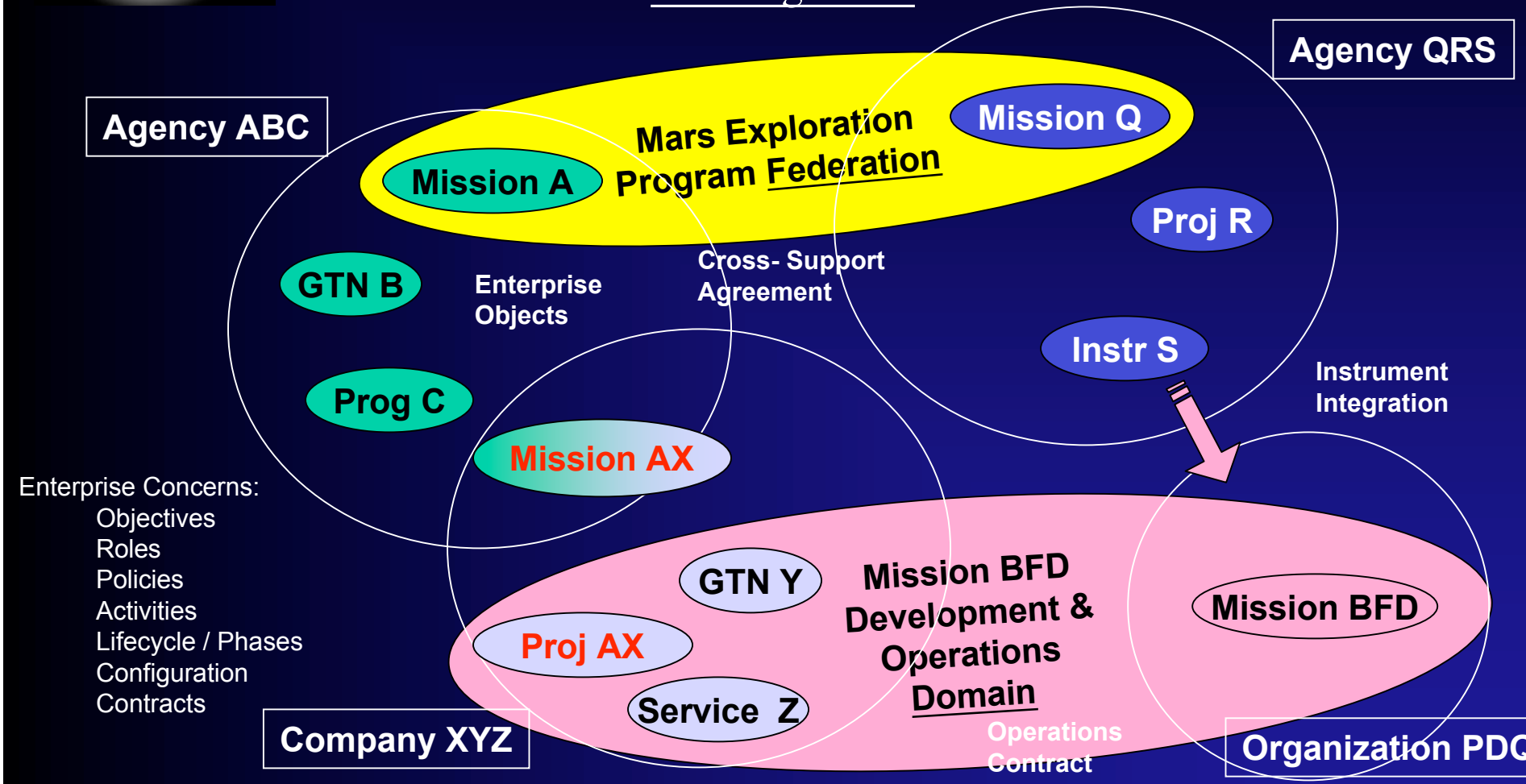
Protocol Concerns
Communications stack perspective

Derived from: RM-ODP

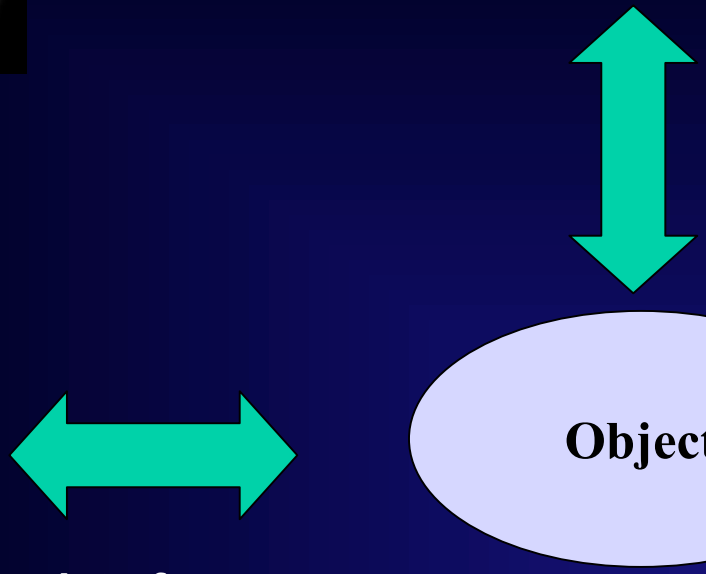
Enterprise View

Federated Enterprises with Enterprise Objects

Planning Phase



Unified Object Representation



Management Interfaces:
How objects are configured controlled, and reported upon

Service Interfaces:
How services are requested & supplied

Core Functions
What the object does

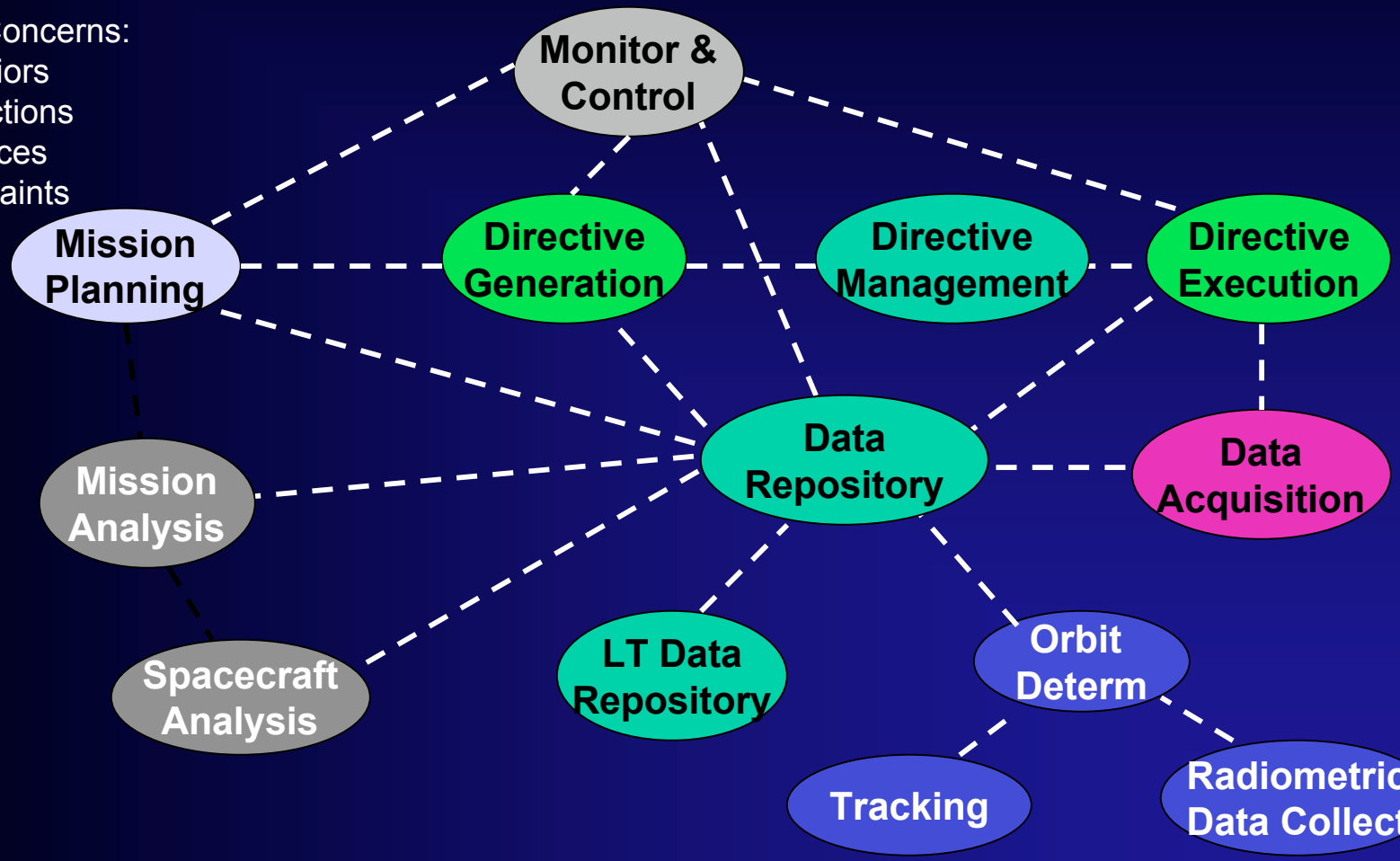
External Interfaces:
How external elements are controlled

Concerns:
Issues
Resources
Policies

Functional View

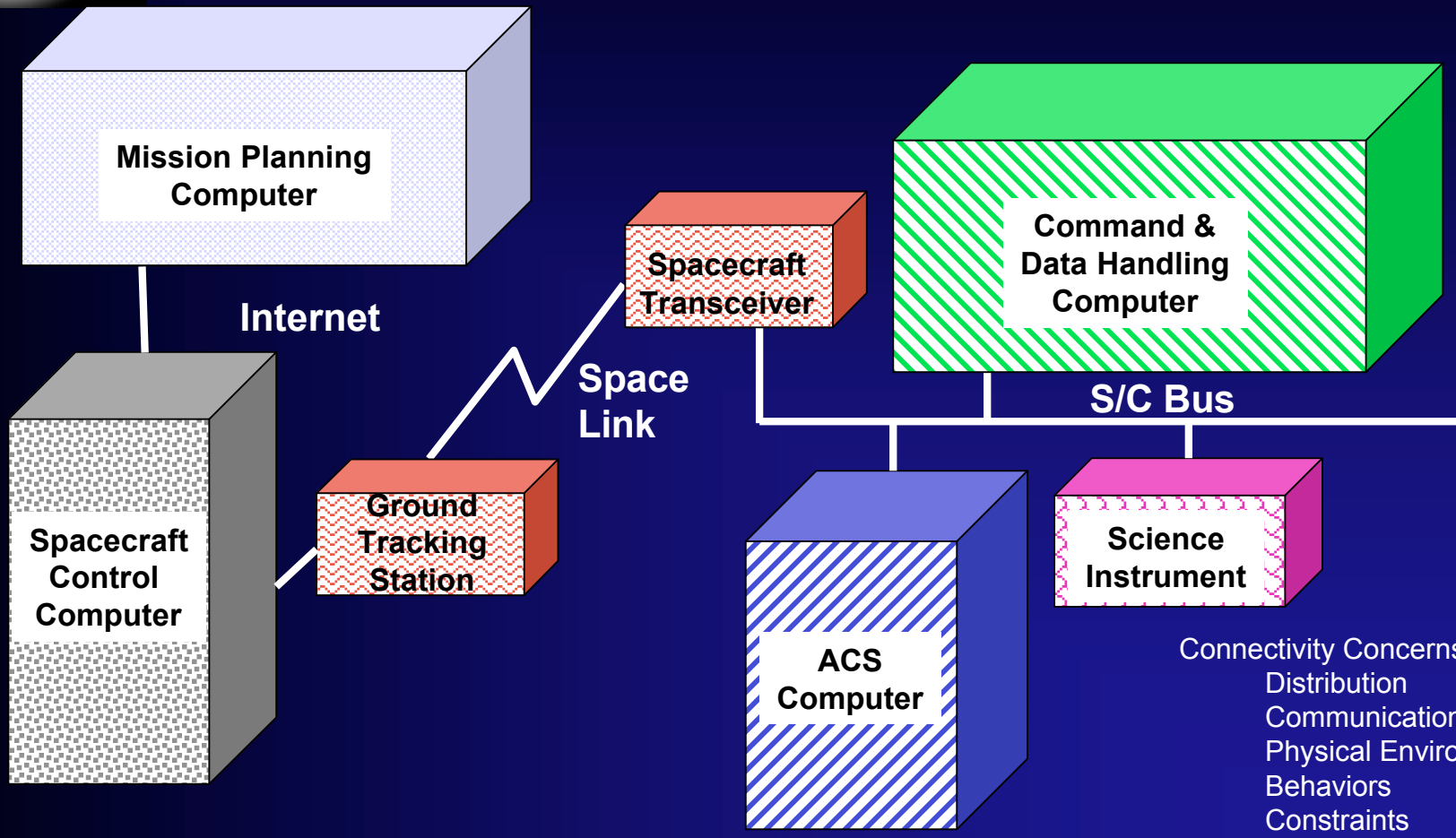
Example Functional Objects & Interactions

Functional Concerns:
- Behaviors
- Interactions
- Interfaces
- Constraints



Connectivity View - Component Level

Nodes & Links



Connectivity Concerns:
- Distribution
- Communication
- Physical Environment
- Behaviors
- Constraints
- Configuration

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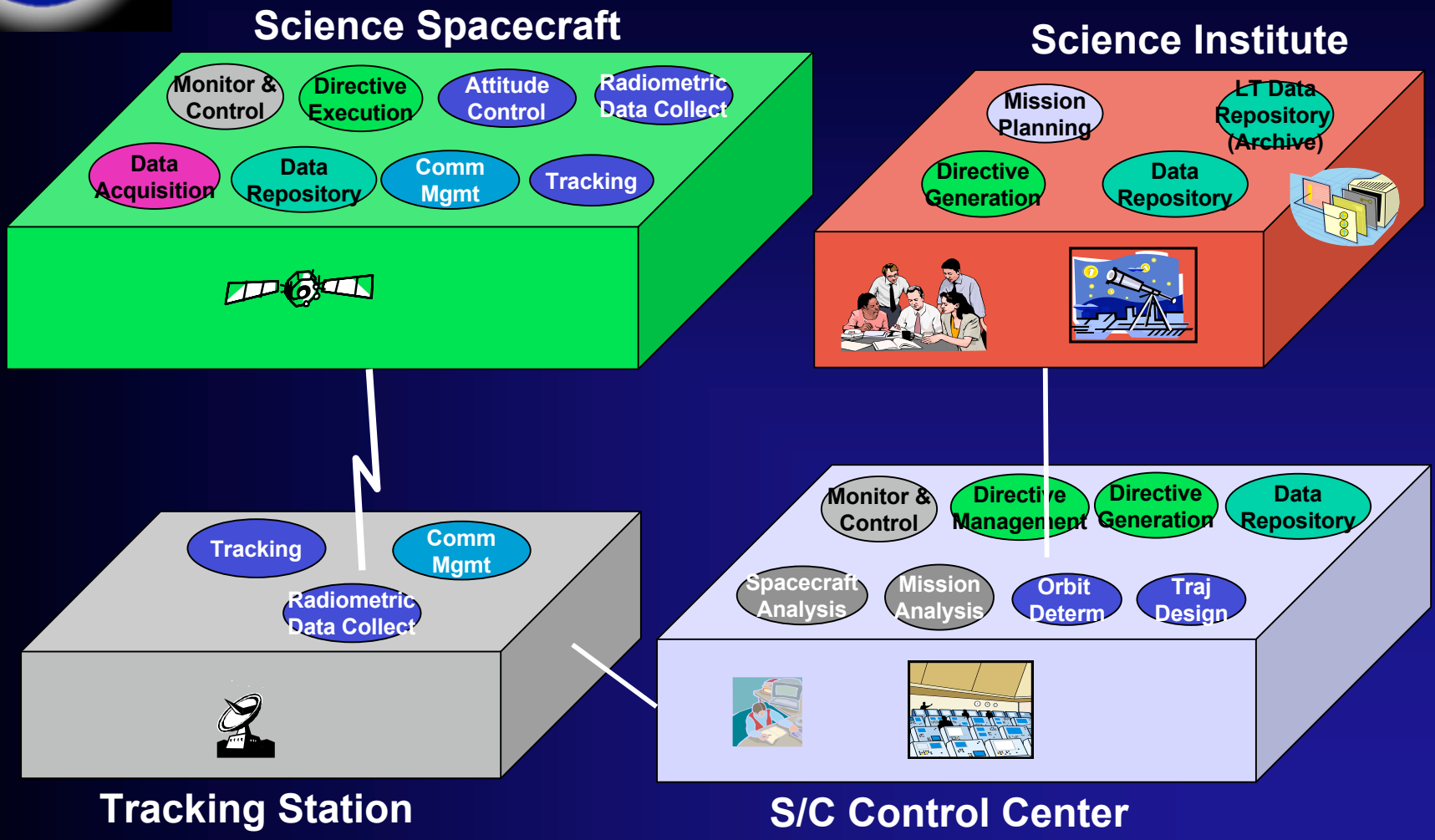
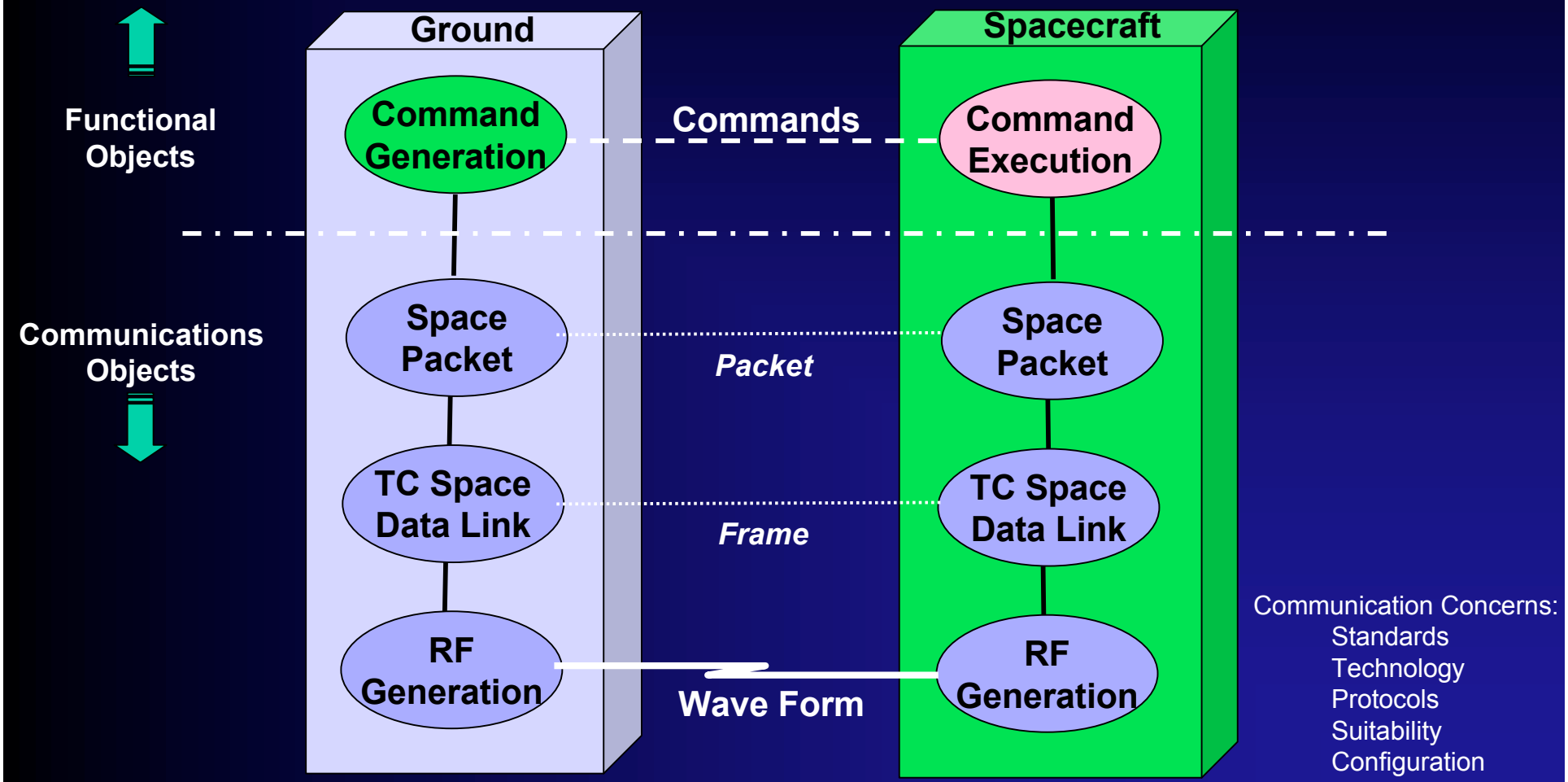
Connectivity + Functional Views

Mapping Functions to Nodes



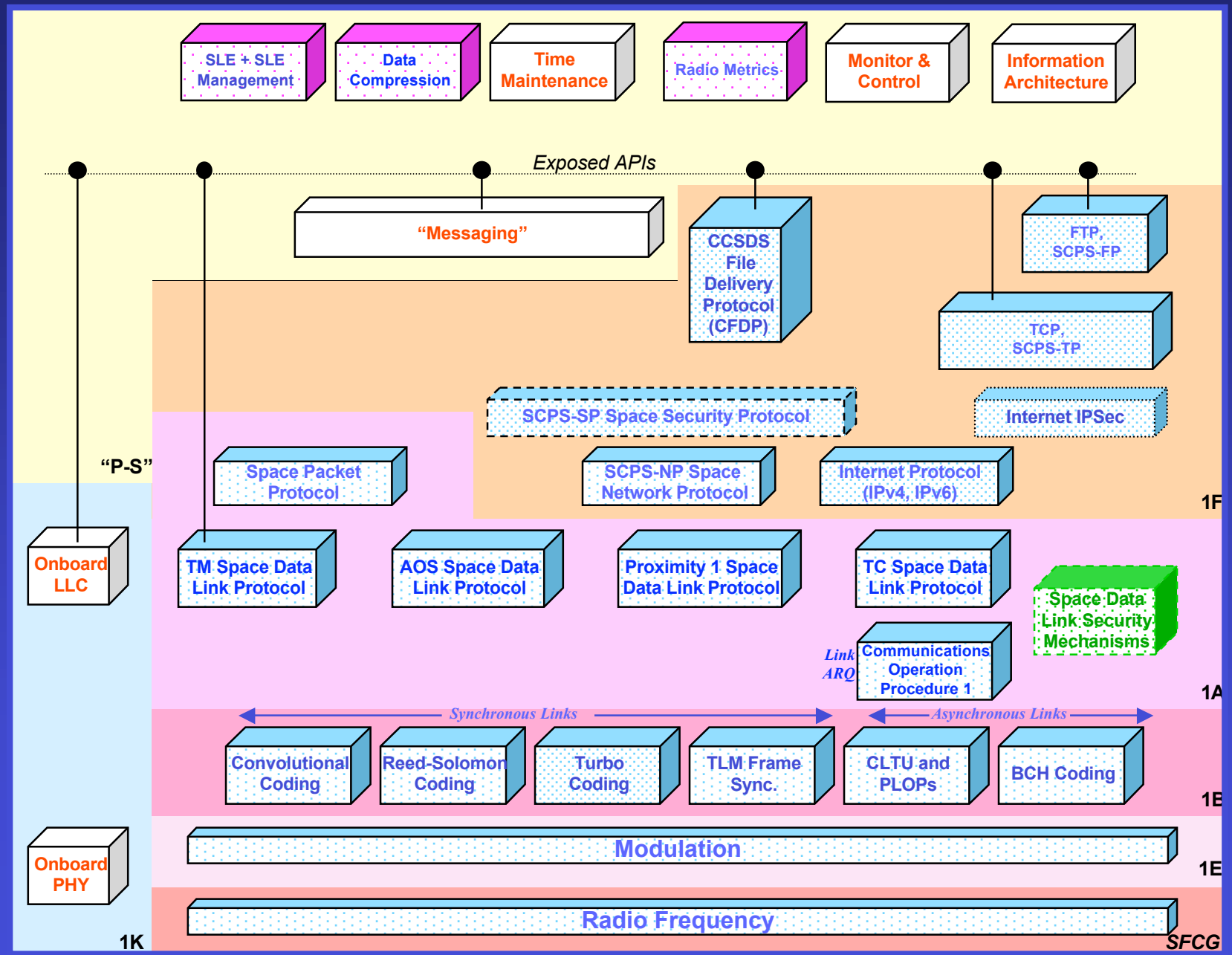
Communications View

Simple Example



Communication Concerns:
- Standards
- Technology
- Protocols
- Suitability
- Configuration

CCSDS Space Communications Standards

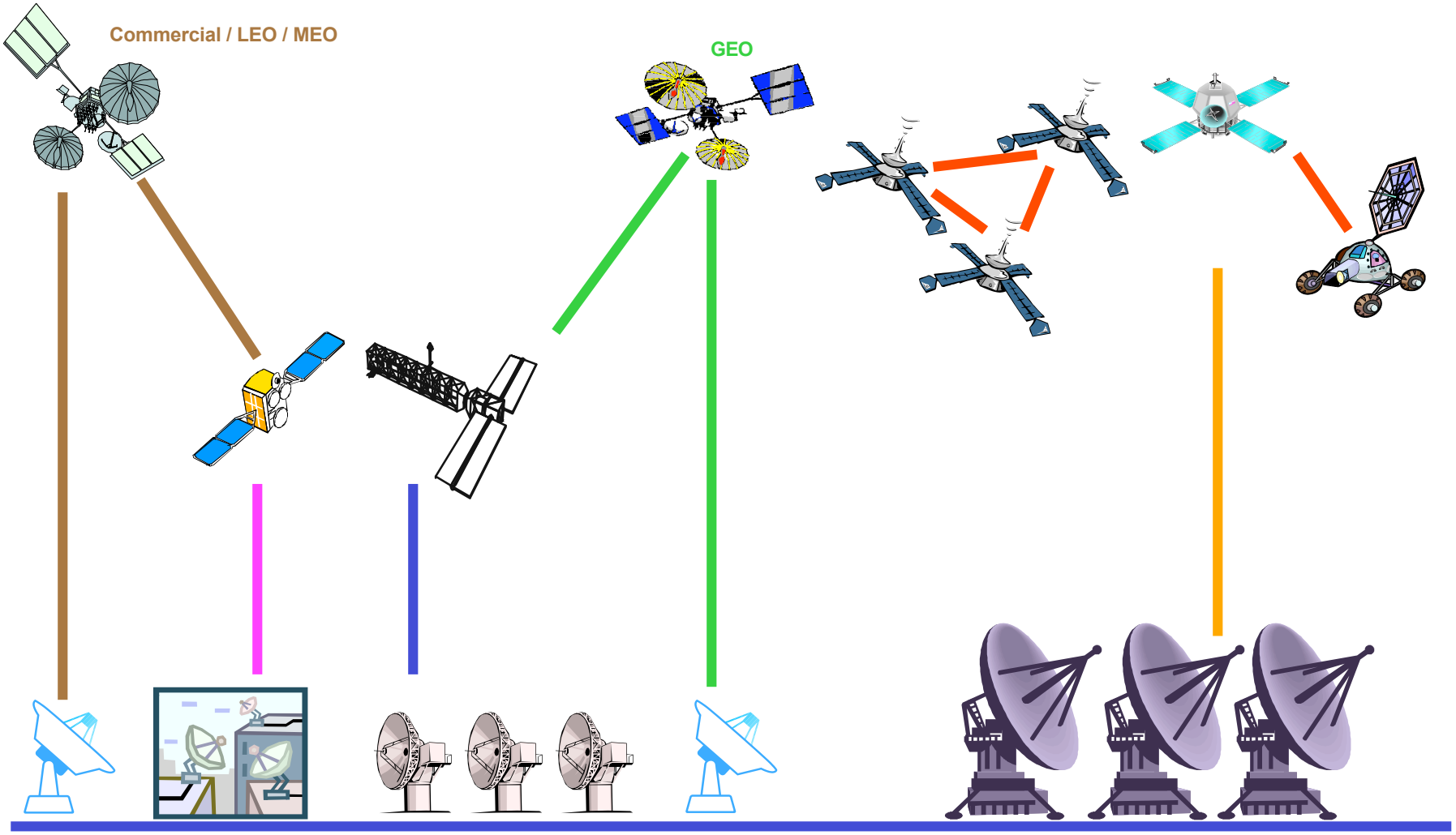


Source: Adrian Hooke, JPL

Application of RASDS to Space Internetworking

- Only a single Functional View example is shown, many are possible
- Types of Space Links
- Connectivity Issues
- Communications Views
  - Near Earth
  - Deep Space
  - Proximity
- Other Considerations

Connector Properties: Types of Space Links



Near-Earth, LEO Direct

Near-Earth, GEO Relay

Near-Earth, Commercial LEO/MEO Relay

Near-Earth, Direct Broadcast

Deep Space Direct (DSN, other)

In-Space Proximity/Relay

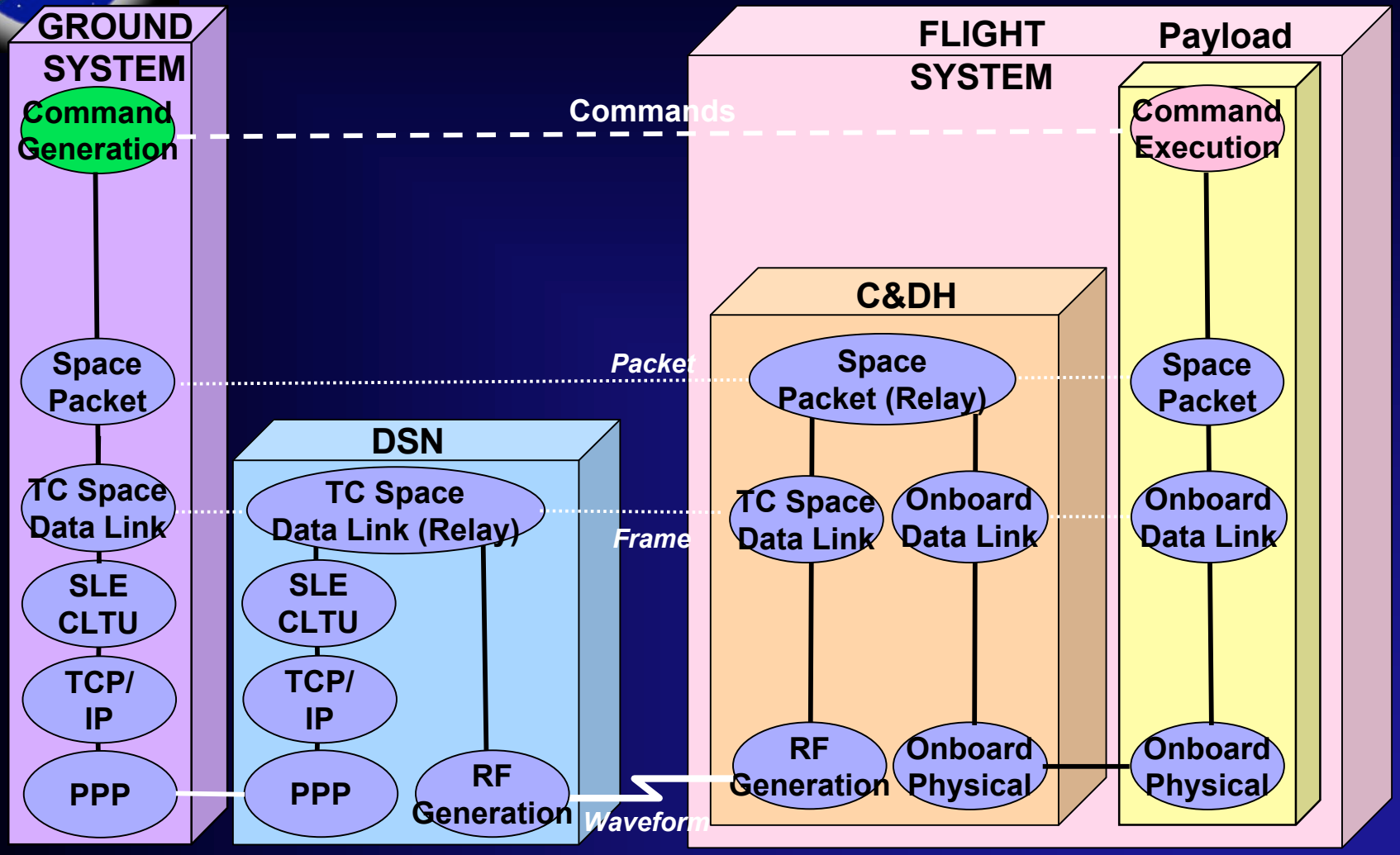
Source: A. Hooke, NASA/JPL

Connectivity Issues

- Near Earth
  - Internet protocol suite will work, modulo short pass times, link (re-)establishment, and modest RTLT issues
  - SCPS protocols (w/ NGSI extensions) recommended solution
- Proximity / In-Situ
  - Internet protocol suite may work, modulo short pass times, link (re-)establishment, and the usual resource issues
  - Resource constraints on landed assets may preclude use of higher level protocols than simple link like Prox-1
- Deep Space
  - Internet protocol suite ***will not*** work, almost every assumption in protocol suite design is violated by physics of environment
  - Possible to transport data between separate Internet-like domains using long haul protocols or new DTN / IPN approach

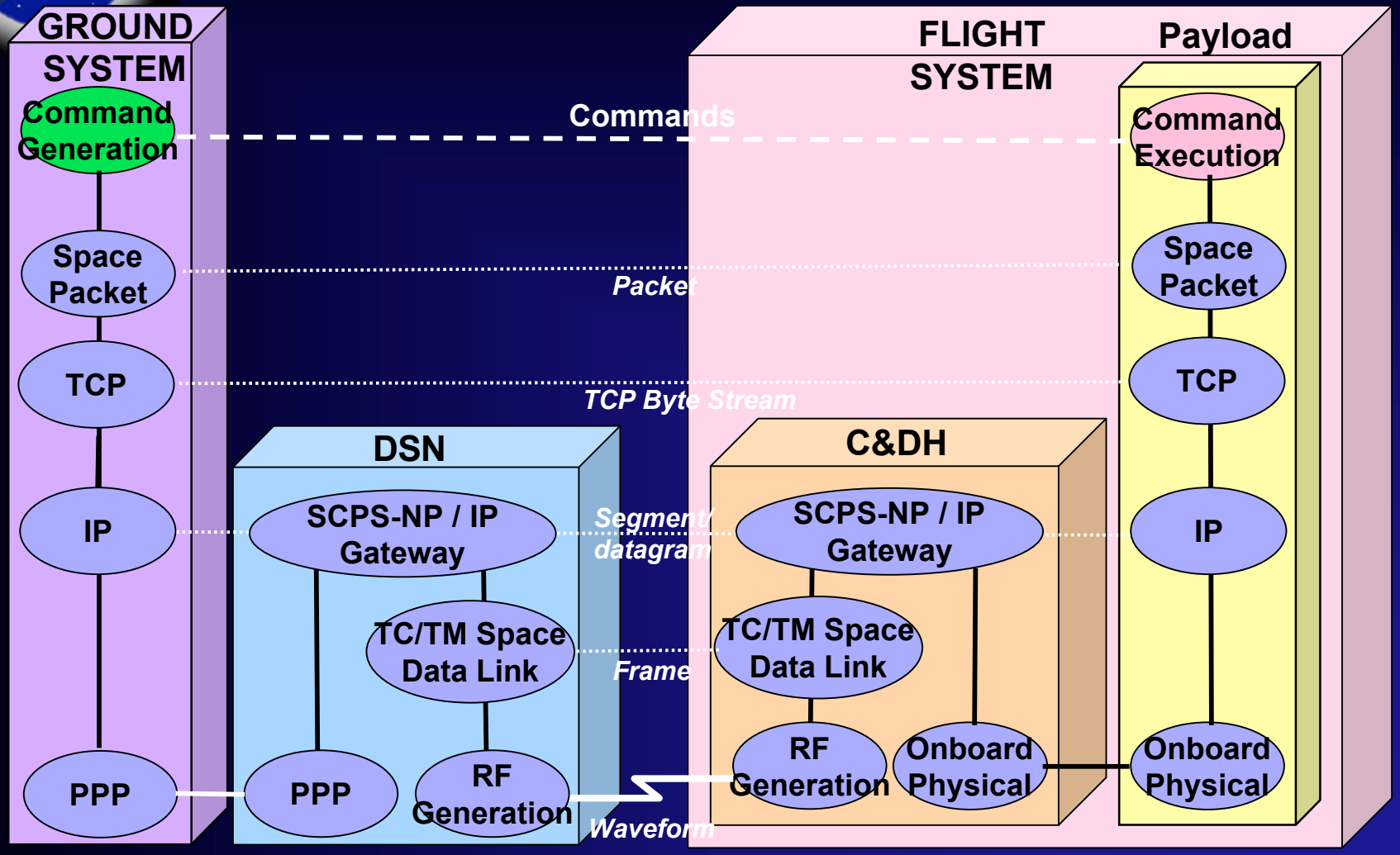
Communications View Composition

(Space Packet Transfer w/ SLE)



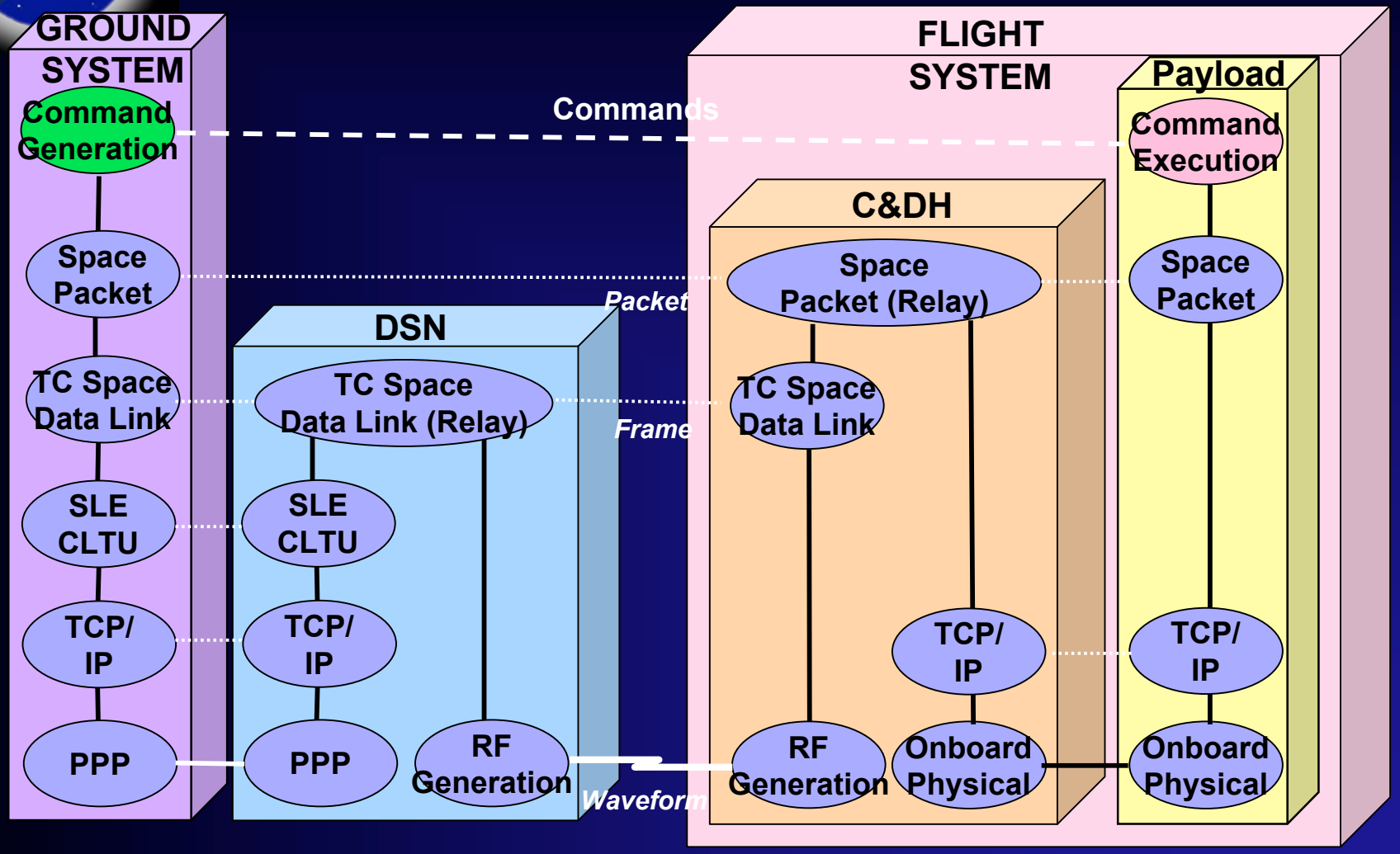
Communications View Composition

(Near Earth Internet Direct)



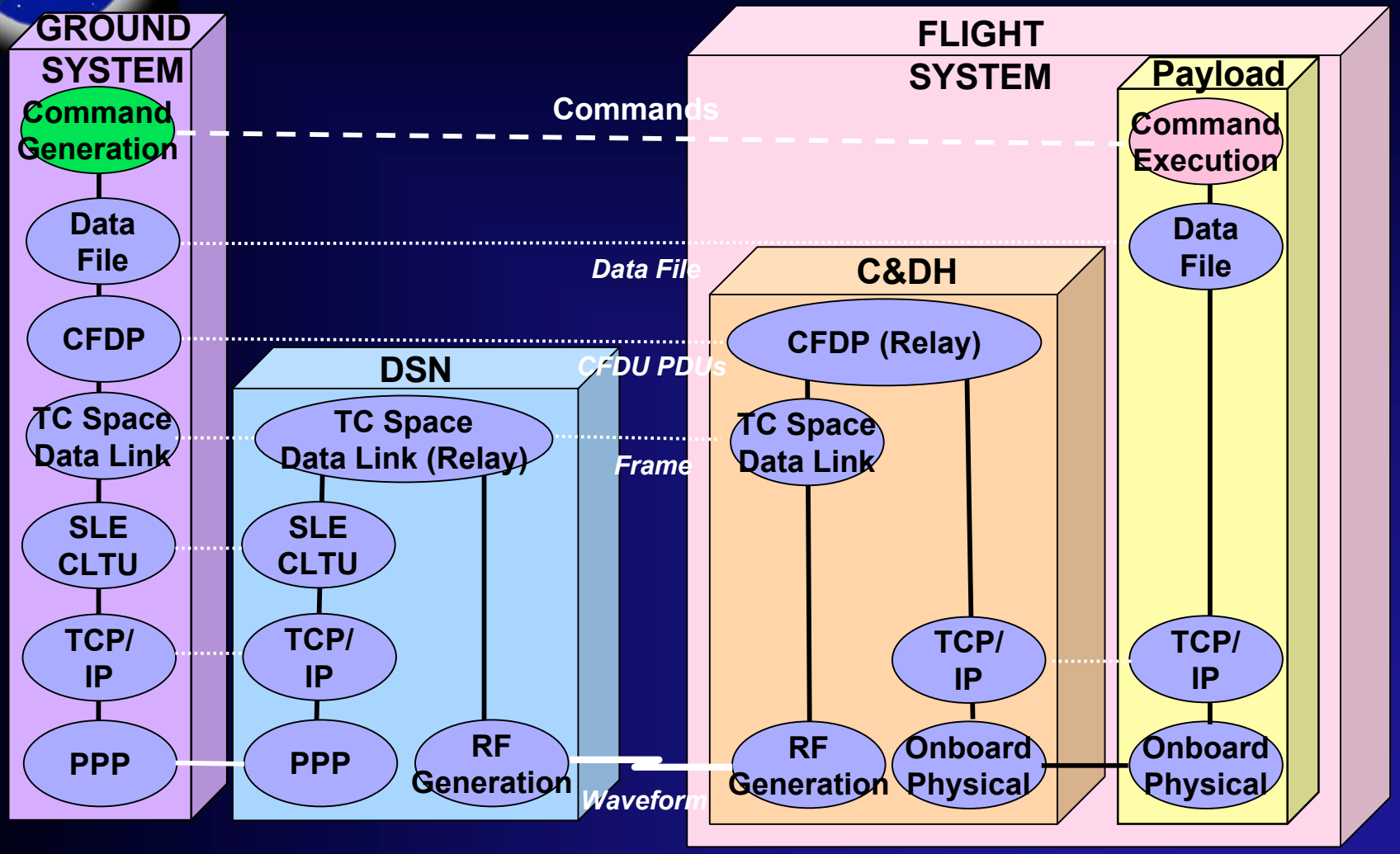
Communications View Composition

(Deep Space Packet Transfer)



Communications View Composition

(Deep Space File Transfer)



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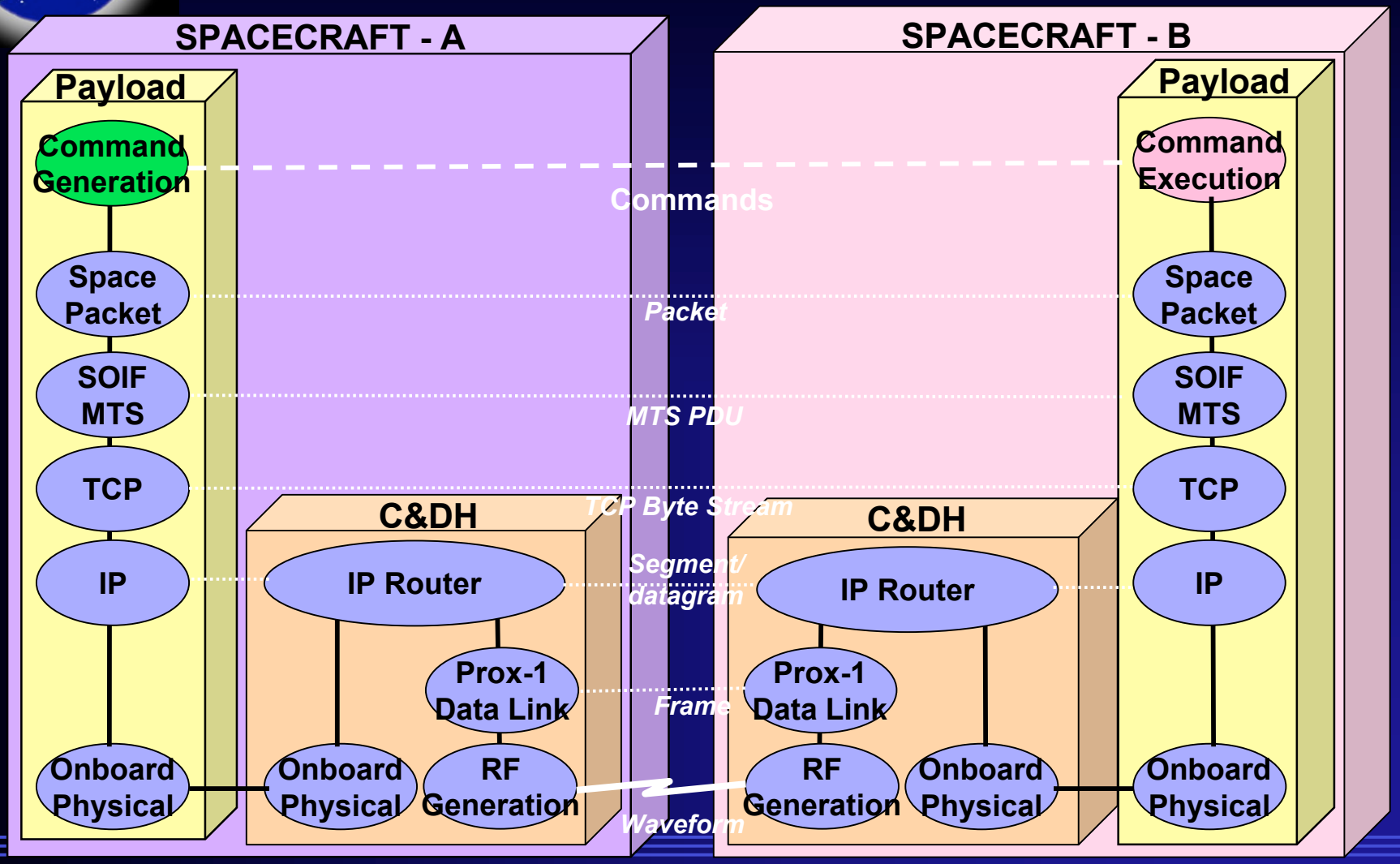
Communications View Composition

(Proximity, S/C to S/C or in Situ)



Other Considerations

- Emergency Commanding
  - How to support this in an Internet environment?
- Security Concerns
  - Maintain Spacecraft Health & Safety
  - Prevent Denial of Service attacks
- Intermittent Connectivity
  - Most standard Internet protocols fail
  - Where do you put recovery mechanisms?
- Installed Base
  - Major multi-agency investment in hardware and software
  - Proven and agreed means to provide interoperability and cross support
  - Commercial suppliers have many space qualified products

Next Steps

- Identify solid mission requirements
  - What are real documented drivers for change?
  - Where are these new techniques appropriate and where do they not work?
- Identify agreed NASA infusion path
  - Work with existing NASA and international space agency supported standards organization, CCSDS
  - Identify ways to evolve existing base to include new capabilities and preserve existing capabilities and functionality
  - Apply Internet technologies only where they make technical and economic sense

Acknowledgements

- The RASDS was designed as part of the program of work of Consultative Committee for Space Data Systems (CCSDS).
- It was performed by the Architecture Working group (AWG), chaired by Takahiro Yamada, ISAS
- Other AWG members who actively participated are listed below:

  - Fred Brosi, NASA/GST
  - Dan Crichton, NASA/JPL
  - Adrian Hooke, NASA/JPL
  - Steve Hughes, NASA/JPL
  - Niklas Lindman, ESA/ESOC
  - Nestor Peccia, ESA/ESOC
  - Lou Reich, NASA/CSC
  - Don Sawyer, NASA/GSFC
  - Peter Shames, NASA/JPL
  - Anthony Walsh, ESA/Vega

BACKUP SLIDES

Rationale

(or, Why do space agencies need standards?)

- Cross-support
  - **Ground assets (e.g. DSN)**
  - **Space assets (e.g. Mars relay)**
- Interoperability
  - **Multi-agency support agreements**
  - **Multi-mission support arrangements**
- Reduce costs
  - **Shared (expensive, scarce) resources**
  - **S/W and H/W reuse**
  - **Commercial implementations**
- Increase reliability / reduce risks
  - **Through use of well tested local and commercial implementations**

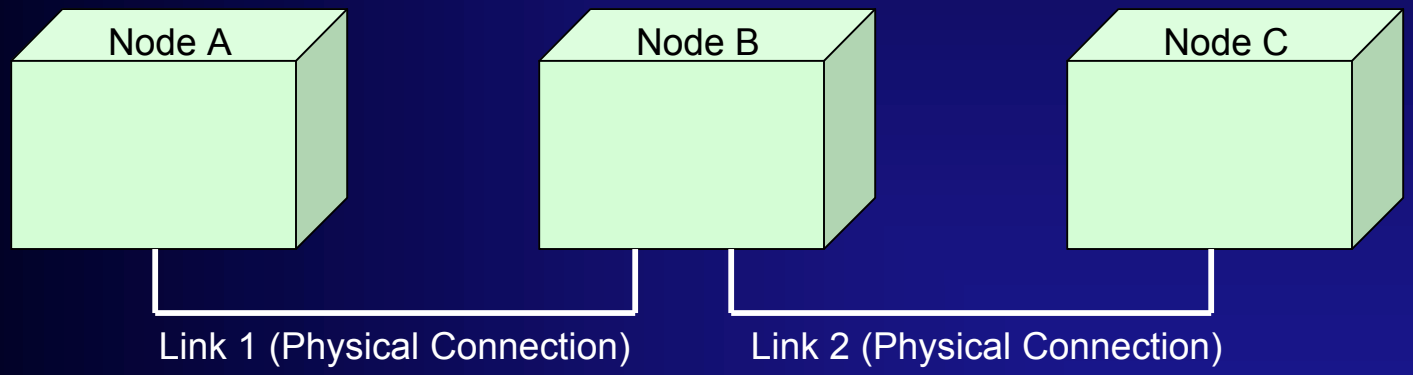
Reference Architecture

Purpose

- Establish an overall CCSDS approach to architecting and to developing domain specific architectures
- Define common language and representation so that challenges, requirements, and solutions in the area of space data systems can be readily communicated
- Provide a kit of architect's tools that domain experts will use to construct many different complex space system architectures
- Facilitate development of standards in a consistent way so that any standard can be used with other appropriate standards in a system
- Present the standards developed by CCSDS in a systematic way so that their functionality, applicability, and interoperability may be clearly understood

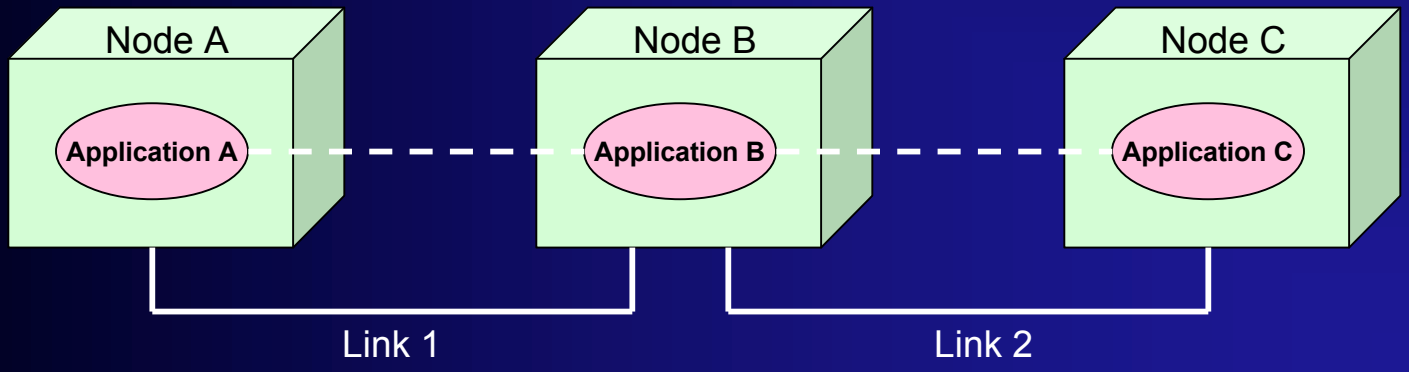
Enterprise View (Enterprise Objects)

Connectivity View (Nodes and Links)



Functional View (Functional Objects)

Connectivity+Functional View (Nodes, Links and Functional Objects)



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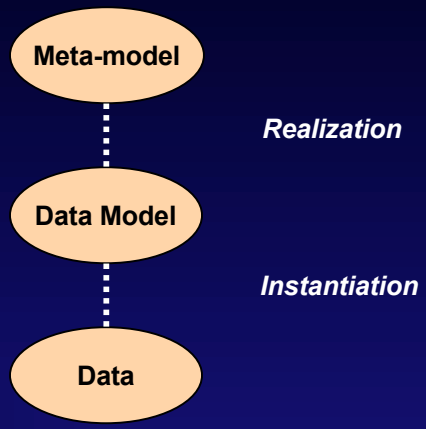
Information View (Information Objects)

Abstract Data Architecture Meta-models

Defined Data Models

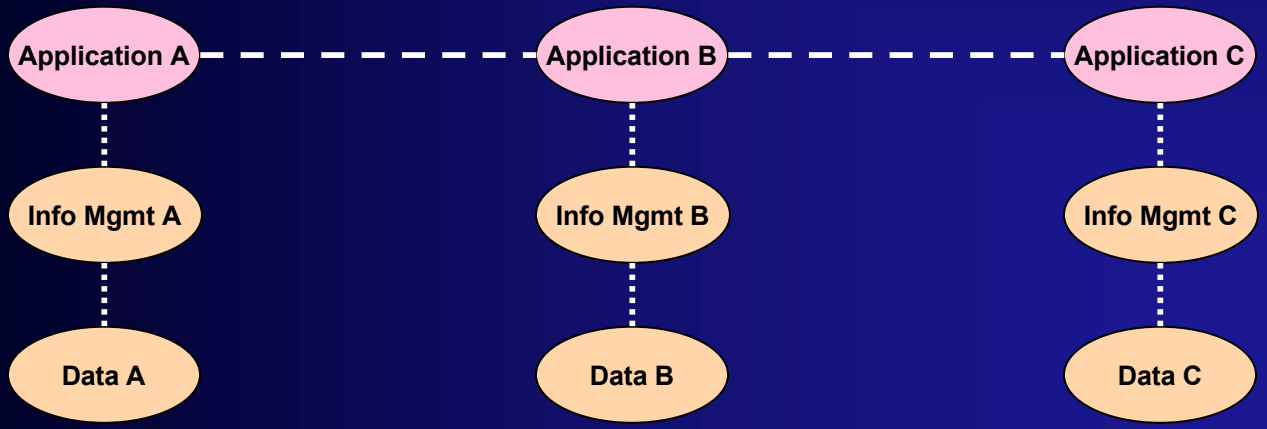
Actual Data Objects



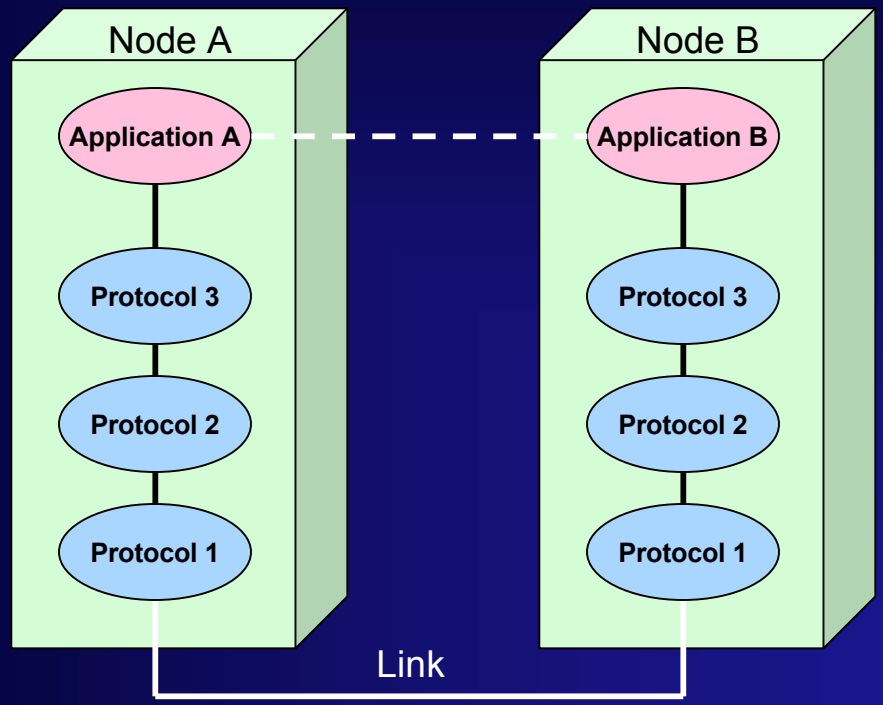
Functional+Information View (Functional Objects and Information Objects)

Information Infrastructure

Data



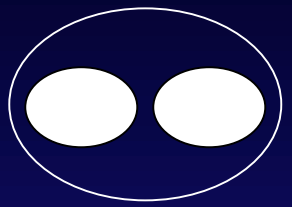
Connectivity+Functional+Communication View (Nodes, Links, Functional Objects and Communications Objects)



Space Data System
Architectural Notation

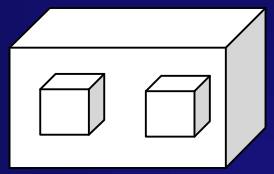
Object

Object with Interface

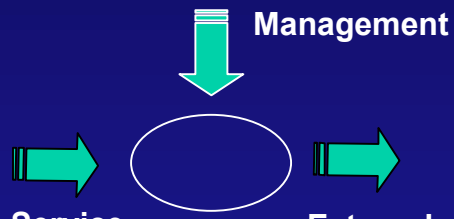


Object Encapsulation

Node
(physical location)



Node Encapsulation
(physical aggregation)



Concerns

Logical Link

Physical Link

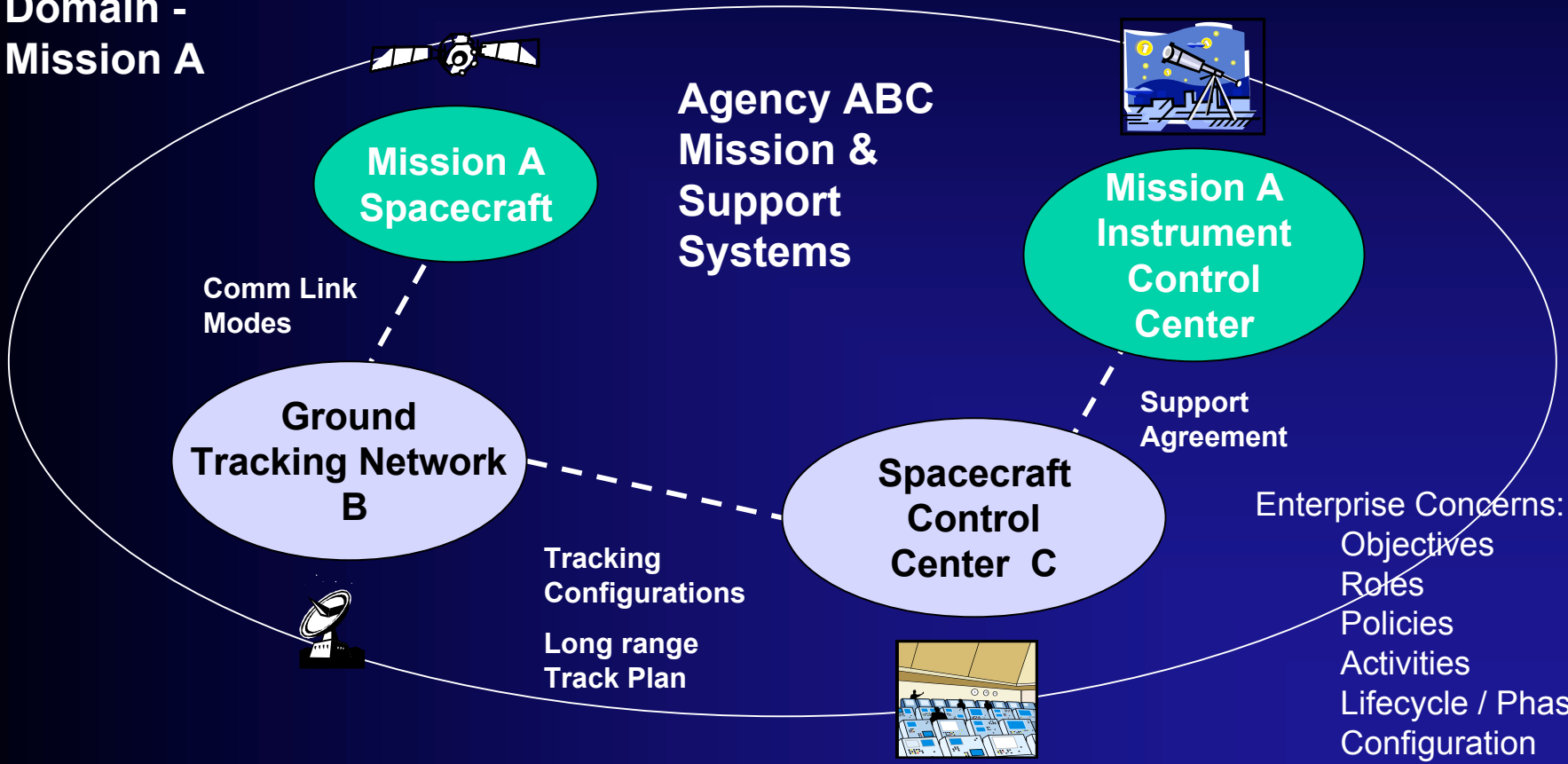
Space Link
(rf or optical)

Enterprise View

Single Agency Mission Domain & Enterprise Objects

Operations Planning Phase

Operations Domain - Mission A

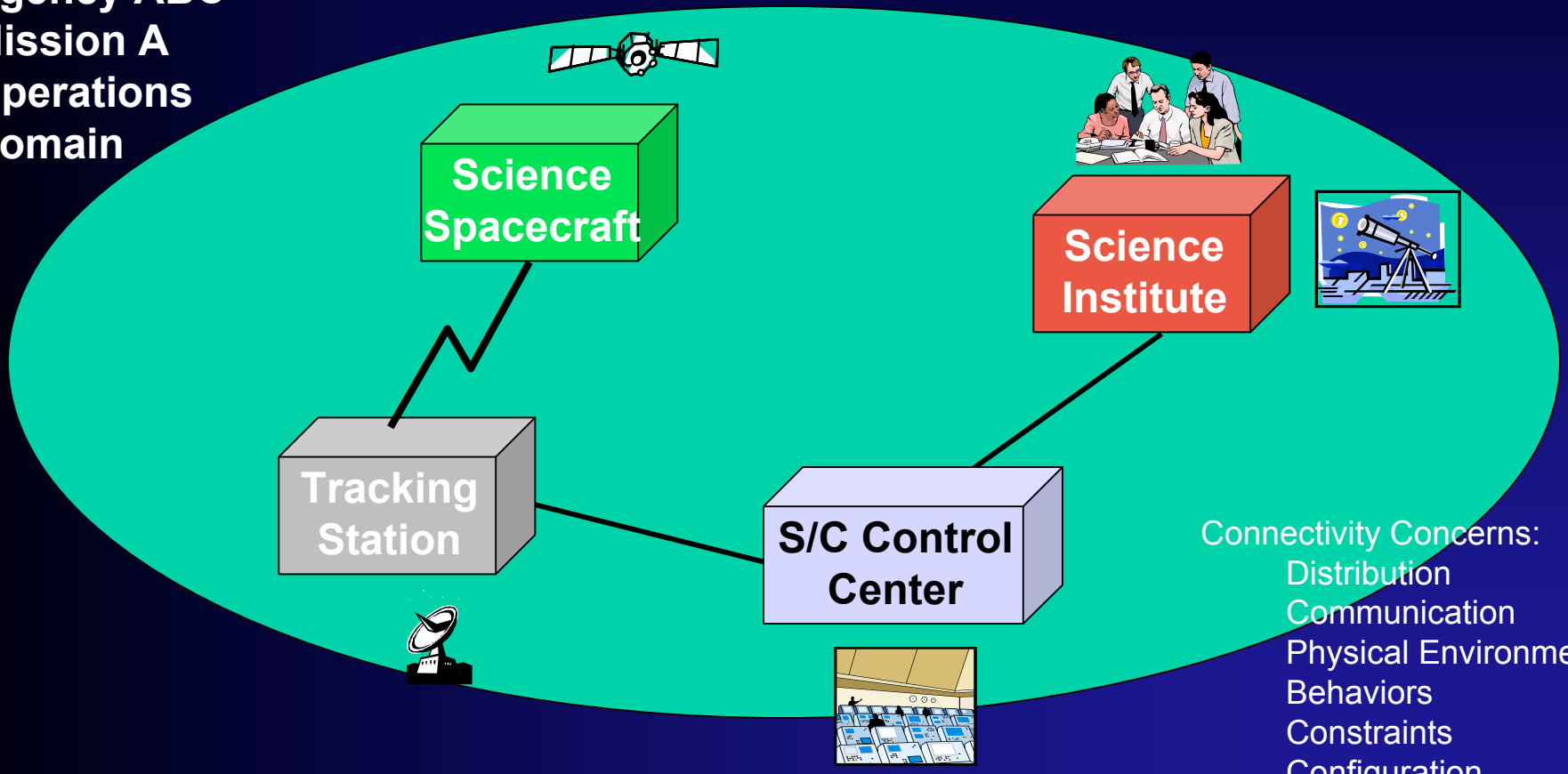


Enterprise Concerns:
- Objectives
- Roles
- Policies
- Activities
- Lifecycle / Phases
- Configuration
- Contracts

Connectivity View - High Level

Single Agency Mission Domain & Nodes

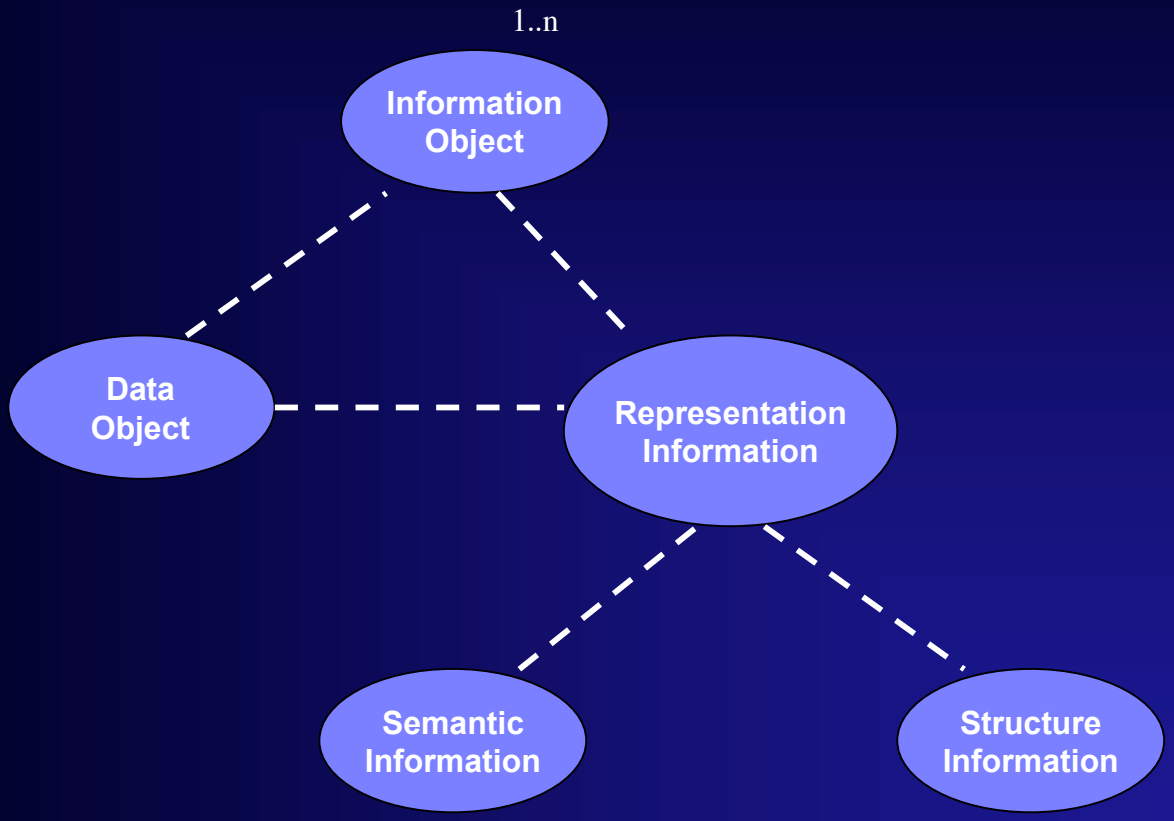
Agency ABC Mission A Operations Domain



Connectivity Concerns:
- Distribution
- Communication
- Physical Environment
- Behaviors
- Constraints
- Configuration

Information Object

Basic Relationships



Information Concerns:
- Structure
- Semantics
- Relationships
- Permanence
- Rules

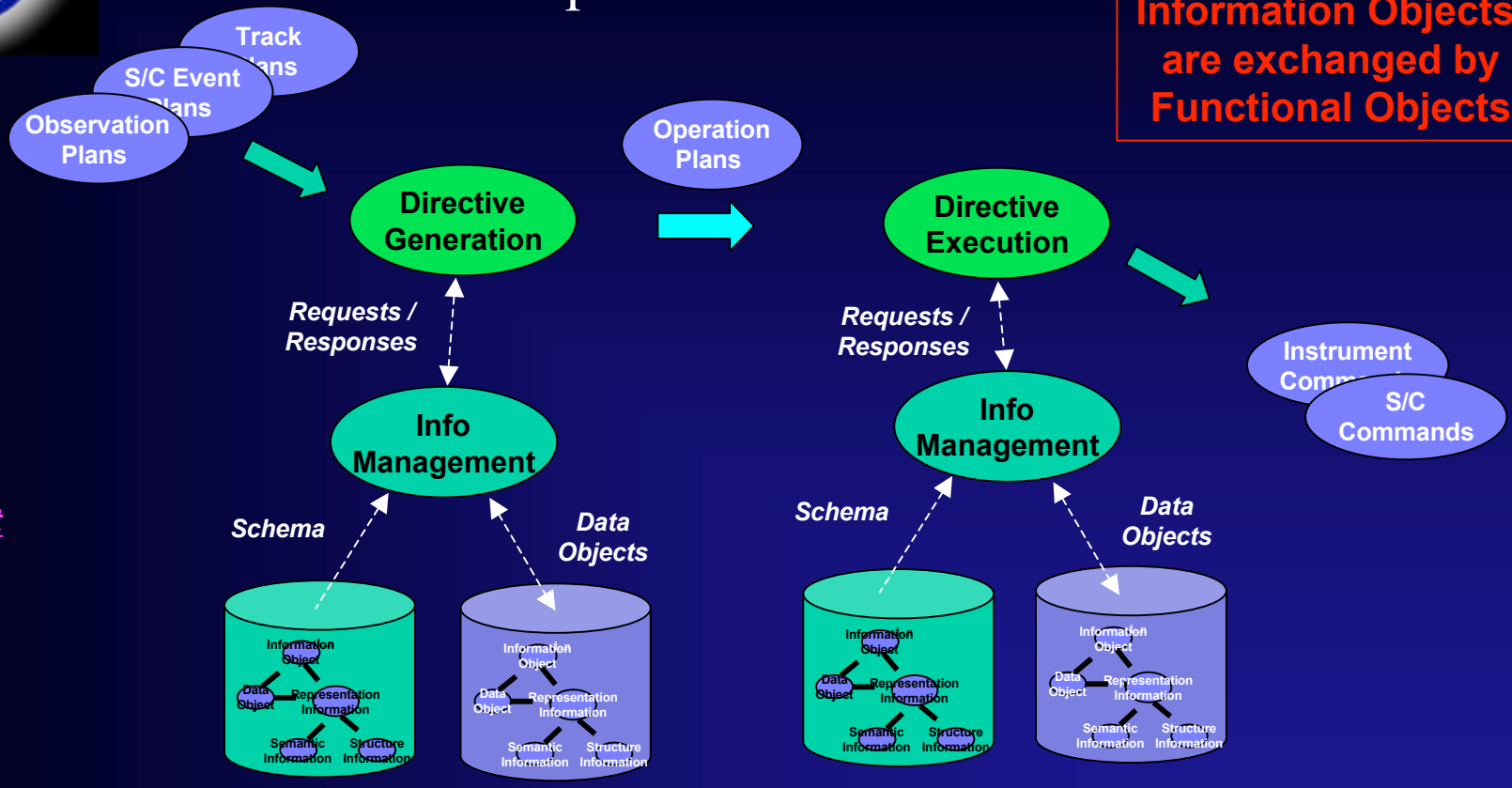
Information Objects

Relationship to Functional View

Information Objects are exchanged by Functional Objects

Example Functional Objects

Information Management Service Objects



Schema & structure may be embedded in the function itself

Obs & Ops Plan Schema & Structure Metadata

Planning Data Repository

Command Schema & Structure Metadata

Command Data Repository

Core Schema
Common Schema
Extension Schema

Communications View

Onboard Decomposition

(Real-time Commanding)